Comments Regarding Specific Data for the Tomsk Area

G/I 231.1
18 December 1957

This report summarizes the results of research on the following three problems:

(1) Water temperature of the Tom' River in the vicinity of Tomsk (56°30'N-84°55'E) on a specified date;

(2) Water temperature necessary to produce visible vapor under specified conditions;

(3) Formula for the rate of heat exchange between water and air.

Problem (1)

Information on the specific water temperature for the Tom' River downstream from Tomsk is not available for the date in question. Furthermore, the climatic and hydrologic data that are available are too fragmentary to estimate the water temperature with any degree of validity. Any estimate that could be derived would be subject to a much greater margin of error than a figure obtained from a simple interpolation from the average monthly water temperatures given in our previous paper (GR - 231).

Problem (2)

An extensive survey of all available meteorological and engineering research on the second problem disclosed the following information. Visible water vapor begins to form under the same conditions as those needed to form "steam fog." Fogs of this type form when relatively cool air moves over a water surface, the temperature of which is considerable higher than the air temperature. The saturation vapor pressure of the water is much greater than the actual vapor pressure of the air above it. Consequently, water evaporates at a rapid rate and immediately condenses as it comes in contact with the colder air, thus filling the air with fog. In cases of extreme temperature differences, "steam fogs" may form even with high winds.

In nature, "steam fogs" occur most frequently at air temperatures near freezing or lower. Observations made on Lake Michigan indicate that the difference between the saturated vapor pressure of the water at a given temperature and the actual vapor pressure of the air is a critical factor. At air temperatures below 0°C. a vapor pressure difference of about 5 millibars* is required to form traces of "steam fog." Thereafter, the density of "steam fog" increases rapidly with small increases in the differences of vapor pressures. At higher air temperatures such as occur in the given problem, however, it is doubtful whether the critical vapor pressure difference of 5 millibars would hold true. Furthermore, it should be noted that even if the Lake Michigan data did include the air temperature specified in the problem, conditions would still not be strictly comparable. In the Lake Michigan observations, the velocity of the wind was not a critical factor, for all the air being moved by the wind to the observation point had been in contact with the water surface, and therefore had a rather uniform vapor pressure. In the present problem, the incoming air has passed over a land surface, and therefore has a different water vapor pressure from the air actually in contact with the limited water surface. From this analysis it is evident that the velocity of the wind is a factor of the greatest magnitude.

In view of the inadequacy of past research on this problem, it is recommended that an actual experiment be conducted to determine the temperature of water necessary to start visible vaporization under the specified conditions.

The following facilities would be necessary to reproduce the necessary conditions:

1. A room in which temperature and humidity can be controlled.

2. A small water trough in which the water temperature can be altered gradually and measured.

3. A variable speed fan to give a specified velocity to the air over the trough.

Such facilities are probably available at the National Bureau of Standards or the Taylor Model Basin. If such an experiment is performed, it is suggested that the temperature and humidity values that were given to us be rechecked beforehand. There appear to be some discrepancies in the data that were examined during the research for this report. These discrepancies may possibly be due to improper allowance for differing time zones and the perpetual Soviet daylight saving time system.

*From which the water temperature could be determined, if the relative humidity of the air is known.

Problem (3)

The rate of heat exchange between the water surface and the adjacent air is primarily a function of the evaporation rate of the water. The difference between the vapor pressure of the water and air together with the wind velocity are the critical factors affecting the rate of evaporation.

The rate of heat exchange between water and still air has been determined experimentally and is expressed by the following formula:

$$H = 97(e' - e)$$

Where H = the heat exchanged in Btu per square foot per hour; e' = the saturated vapor pressure of the water at the given temperature in inches of mercury; e = the actual vapor pressure of the air at the given temperature in inches of mercury.

The rate of heat exchange increases in nearly direct proportion to the wind velocity when the other conditions are constant. The following formula for heat exchange takes into consideration the effect of air movement parallel to the water surface:

$$H = 97(1 + v/230)(e' - e)$$

Where H = the heat exchanged in Btu per square foot per hour; v = the velocity of air over the water surface in feet per minute at 70°F and 29.92 inches pressure; $e' - e$ = the difference in vapor pressures between water and air in inches of mercury.

The saturation vapor pressures of water at various temperatures are readily available in tables in both meteorological and engineering handbooks. The actual vapor pressure of the air can be similarly determined if the relative humidity and temperature of the air are known. This office can supply any specific values that may be required.